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An enterprise-wide model for redistributing excess material

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NAVAL POSTGRADUATE SCHOOL

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MBA PROFESSIONAL REPORT

An Enterprise-Wide Model for Redistributing Excess Material

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December 2012

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For the last 10 years, the Navy has been consolidating its major business functions into an Enterprise Resource Planning (ERP) system to increase efficiency, reduce costs, and improve accountability. Much of this effort has focused on integrating information and standardizing business processes at the corporate level. Individual fleet units, such as ships and aircraft squadrons, have been largely left out.

The decentralized management of fleet inventory often produces suboptimal results when viewed from the enterprise level. One of the most serious problems in the current model is investment in excess inventory. For example, in April 2012 nearly $171 million in system-wide inventory deficiencies could have been filled with excess material onboard fleet units. We approach this problem from both a short-term and a long-term perspective. In the short term, we analyze fleet inventory levels and show how a mixed-integer program could be used to efficiently redistribute this material while minimizing cost. For the long-term, we describe an enterprise-wide redistribution model, based on corporate lateral transshipment models, that uses ERP to automatically source requisitions to fleet units. We present three different logic trees to describe how such a model might be incorporated into ERP's sourcing function.

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AN ENTERPRISE-WIDE MODEL FOR REDISTRIBUTING EXCESS MATERIAL

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Submitted in partial fulfillment of the requirements for the degree of

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AN ENTERPRISE-WIDE MODEL FOR REDISTRIBUTING EXCESS MATERIAL

ABSTRACT

For the last 10 years, the Navy has been consolidating its major business functions into an Enterprise Resource Planning (ERP) system to increase efficiency, reduce costs, and improve accountability. Much of this effort has focused on integrating information and standardizing business processes at the corporate level. Individual fleet units, such as ships and aircraft squadrons, have been largely left out.

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LIST OF ACRONYMS AND ABBREVIATIONS

COSAL:	Coordinated Shipboard Allowance List
CONUS:	Continental United States
FIMARS:	Fleet Inventory Management Analysis Reporting System
ERP:	Enterprise Resource Planning
NAVSEA:	Naval Sea Systems Command
NAVSUP:	Naval Supply System Command
NIIN:	National Item Identification Number
NWCF:	Navy Working Capital Fund
TOO:	Target of Opportunity
UIC:	Unit Identification Code

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I. INTRODUCTION

A. PROBLEM BACKGROUND

For the last 10 years, the Navy has been consolidating its major business functions into an Enterprise Resource Planning (ERP) system to increase efficiency, reduce costs, and improve accountability. Much of this effort has focused on integrating information and standardizing business processes at the corporate level. Individual fleet units, such as ships and aircraft squadrons, have been largely left out. The current fleet supply-support plan continues to use the traditional multi-echelon, distributed-data model that replicates information from master databases into unit-level software applications and transfers decision-making responsibility to ship and squadron personnel.

The traditional supply-support model has served the Navy well for many years. However, it is not without its shortcomings. This decentralized system often produces suboptimal results when viewed from the enterprise level.

One of the most serious problems in the current model is investment in excess inventory. For example, we analyzed fleet inventory data from April 2012 and found that nearly $171 million in system-wide inventory deficiencies could be filled with excess material the Navy had already bought. While there are procedures for managing subsets of this material, the current operating model does not have an enterprise-wide process for redistributing excess material to units that need it. This means many units will waste money buying items that are readily available and for which the Navy has already paid.

B. PURPOSE OF THE STUDY

Investing in excess inventory imposes an opportunity cost on the Navy. That $171 million from April 2012 could buy a lot of different things—four F/A-18 fighter aircraft, or a Littoral Combat Ship mission module—but it likely will be spent buying new inventory. Given the climate of fiscal austerity in late 2012, the Navy is going to have to get more readiness and more capability from every dollar it spends. The service can not

afford to waste millions buying items it already has. So how can the Navy, and particularly the Naval Supply Systems Command (NAVSUP), get more value from its inventory investment?

The focus of this study is to develop a methodology for systematically redistributing excess material across the enterprise to save money. Previous works have focused either on how to reduce the creation of excess inventory or how to better manage redistribution among certain categories of material. We are examining an enterprise-level solution from two perspectives. In the short run, we identify how much excess material is currently available for transfer and define the business rules to govern its redistribution. For the long term, we develop a redistribution model that could be used within Navy ERP to systematically govern transfers of excess material.

C. RESEARCH QUESTIONS

This research tackles three main questions.

- In the short term, how might NAVSUP redistribute excess material to realize significant one-time savings?
- For the long term, how might a redistribution model work within the ERP framework?
- What are the potential benefits of incorporating a redistribution model into ERP?

D. METHODOLOGY

For the short-term solution, we analyzed data from the Force Inventory Management Analysis Reporting System (FIMARS) to determine the amount of excess material and deficiencies for the entire system, for each warfighting enterprise (e.g., aviation, surface, and undersea), and for each geographic region. We then used mixed-integer programming to institute a set of business rules and ran a Monte Carlo simulation to estimate the average cost avoidance of redistributing material.

For the long-term solution, we developed a redistribution model based on previous academic research. The model used supply data from April 2012 to track how one NIIN could be redistributed among the eleven active Aircraft Carriers. We then used

linear programming to institute a set of business rules governing redistributions to estimate the effects of these transfers on average lead time and inventory levels.

E. ORGANIZATION OF THE PAPER

Chapter II describes how items become excess and reviews the current processes for handling this material. In Chapter III, we analyze recent fleet inventory data and discuss the business rules needed to redistribute this material. In Chapter IV, we explain its short-term redistribution model and summarizes the results of running an inventory sample through the model. Chapter V describes our assumptions and methodology behind the business rules in greater detail. Finally, we present its conclusions in Chapter VI.

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II. THE CURRENT MODEL FOR EXCESS MATERIAL

A. INTRODUCTION

Before proceeding, we must first define excess inventory and review the Navy business processes that relate to it. This paper uses the same definition as Volume I of the NAVSUP Publication 485, "Afloat Supply." *Excess inventory* includes:

- any material held above the approved allowance level for that organization. An *allowance* is the amount of any particular item a naval organization is authorized to hold in inventory.
- any material categorized under allowance type codes 6, 7, or 8. An *allowance type code* describes why the material is stocked; these particular codes identify items that are not currently part of the authorized inventory list. (Afloat Supply, 2005)

The Navy operates a multi-echelon supply system with two levels of inventory, retail and wholesale. This research is primarily concerned with excess inventory at the *retail level*; that is, the excess material on ships, submarines, and aircraft squadrons that make up the fleet. This is the material used by individual fleet units use to sustain their operations. It is supported by the *wholesale level*, a globe-spanning network of resupply ships, support bases, and distribution centers.

This chapter presents the background information needed to understand the challenges of redistributing excess material. We first review the process by which the Navy establishes and updates allowances. We then present the most common reasons that inventory becomes excessive. Finally, we discuss how the Navy funds allowances and its implications on redistributing excess inventory.

B. ESTABLISHING THE INITIAL ALLOWANCES

The Navy uses different mathematical models to calculate allowances for different types of units and for different categories of material. A detailed review of these models is beyond the scope of this paper. Instead, we limit our discussion to four key variables that are common to most of the allowancing models.

The primary source for this information is the *COSAL Use and Maintenance Manual* (2009), which is published by NAVSUP Weapons System Support. COSAL is an acronym for Coordinated Shipboard Allowance List; it is a supply and technical document that provides information about a unit's equipment and the items needed to support it. There is a similar process and a similar document for aviation units and for shore installations.

Based on the COSAL manual, a unit's allowance quantity for a particular item is a function of:

- <u>Population</u>. How many pieces of equipment at the unit does this item support?
- <u>Failure rate</u>. This may be based on actual data (for equipment that has been in service for many years) or on an engineering estimate (for new items), according to the COSAL manual (2009).
- <u>Cost</u>. Some models weigh cost differently to prevent very cheap or very expensive items from skewing the allowance quantities (COSAL manual, 2009). Note that the higher the unit price, the greater the opportunity cost of holding inventory.
- <u>Overrides</u>. This category includes technical overrides, planned maintenance requirements, fleet casualty report data, and other factors that influence actual expected usage (2009).

C. UPDATING UNIT ALLOWANCES

The initial allowances are not the end of the story, however. Over time, new technology and better components is incorporated into the fleet. Even for items that remain the same, actual inventory usage may change over time.

There are several processes that update a unit's allowances. We divide them into two groups: configuration changes and demand changes.

Configuration changes involve changes to installed equipment or, in the case of aircraft carriers, changes in the composition of the embarked air wing. For ships and submarines, major changes to equipment are usually made during maintenance periods (COSAL manual, 2009). These changes occur as collaboration between the Naval Sea Systems Command (NAVSEA), which has the technical authority for equipment, and NAVSUP, which is responsible for supply support (COSAL manual, 2009). For aircraft

carriers, aviation allowances are a based on the type and number of aircraft to be deployed, according to a retail-level inventory instruction by NAVSUP Weapons System Support (2008). These changes occur as collaboration between Commander, Naval Air Forces (NAVAIR) and NAVSUP. In both cases, the changes are typically delivered through an Automated Shore Interface file that updates the unit's database.

Changes based on demand are a little different. The actual demand may be different from the expected demand, causing the unit to carry too much or too little. In some cases, the unit can update its own allowances (usually for low-price items). In other cases, the unit can ask its Type Commander (e.g., Naval Submarine Forces) or NAVSUP Weapons System Support to update the allowance. Finally, if demand for an item across the fleet is consistently different from the expected demand, NAVSUP and the technical authority (e.g., NAVSEA) may collaborate to change the allowance.

D. HOW DOES MATERIAL BECOME EXCESSIVE?

There are many reasons why an item may become excessive. Gilmore, Klemm, and Sweetser (2011) described these reasons in detail. We consolidated them into five categories:

- Configuration changes. The Navy replaced one piece of equipment with another, and the old items do not support the new piece of equipment.
- Allowance changes. An Automated Shore Interface file reduced the allowance quantity because fewer items are needed to support the installed equipment (e.g., actual usage is less than expected).
- Changes in item disposition. Any item that is obsolete or defective is considered to be excess. Price changes also influence the amount of excess. Very cheap items are usually allowed to be carried in excess without penalty. However, if the price increases above a certain threshold, the previously exempted items must be reported as excess.
- Level settings. The unit-level supply databases have a function, commonly called a level setting, that can update some allowance quantities based on demand during a specified period.
- Improper unit-level inventory management. This category encompasses all the bad habits that lead to inventory discrepancies. One common problem is poor receipt and issue practices, which can result in gains by inventory (e.g., an item that was previously written off is rediscovered).

> Another problem is offline ordering, where a unit places an order in the wholesale system without recording it in the unit database. (Gilmore et al., 2011)

The first four categories include common processes used to ensure units have the right items to support the equipment and aircraft they actually have. However, it is important to note that failing to follow these processes can also result in excess material. Suppose a unit never processed the Automated Shore Interface increasing its allowance for an item. The unit may be forced to order more than the allowed amount to sustain operations, and its inventory reports will show this as excess material.

E. FUNDING AND ALLOWANCES

Who paid for the inventory has important implications for any attempt to redistribute the excess items. The initial allowances are usually funded through the Navy's procurement accounts. The money used to replenish the original stock, though, varies by unit. Capitalized ships, such as aircraft carriers and amphibious assault ships, use the Navy Working Capital Fund (NWCF). Smaller units (i.e., ship's budget) use their own mission funds.

The capitalized ships are like floating warehouses; they use the NWCF to replenish their allowances and then charge their mission funds as they use the material. Like other working capital funds, the NWCF is a revolving fund used to finance the purchases of material and maintenance needed to support operations. The smaller ships, however, must use their own mission funds for items they need immediately and to replenish their allowances. Herein lies a complication. The NWCF material belongs to the Navy. The capitalized ships do not own the material until they actually use it and replenish the NWCF with their mission funds. Until that time, the material can be transferred to any other organization using the NWCF, including wholesale distribution centers, without concern for reimbursement. The material at small ships and at aircraft squadrons, however, already belong to those units *because they used mission funds to buy it*. Any redistribution, therefore, must consider how those units get reimbursed for having bought the material. We address this issue more fully in Chapter III.

F. CURRENT PROCEDURES FOR HANDLING EXCESS

The procedures for handling excess inventory depend on the category of material and the type of unit.

Within the Navy, there are two broad categories of material: Depot Level Repairables and consumables. Depot Level Repairables (DLRs) are items that can be repaired and reused many times. They are often expensive end-items or major subassemblies, such as valves, manifolds, and radar receivers. In contrast, consumables are one-time-use items such as gaskets, screws, and filters.

The procedures for handling excess DLRs are the same for all units. If the DLR is broken, the unit should turn in the item to an Advanced Traceability and Control site, according to the Afloat Naval Supply Procedures (2005). If the DLR is ready for issue, it should be turned into a wholesale distribution center for reuse (Supply Procedures, 2005).

The procedures for handling excess consumable items vary by unit type. For the capitalized ships, NAVSUP manages the Consumable Asset Reutilization Program. Gilmore et al. (2011) studied this program in detail and offered some recommendations for improving its utilization. The smaller ships and aircraft squadrons turn in their excess material to wholesale distribution centers (Afloat Supply, 2005).

These wholesale distribution centers typically reimburse the type commander, not the individual unit, for the value of the excess items. One notable exception involves relatively cheap consumables. The distribution centers do not give credit for items with an extended monetary value less than $100 “due to the cost of processing such credits” (Afloat Supply, 2005).

The Afloat Supply Procedures (2005) also support a process called Other Supply Officer transfers, which allows enterprising units to arrange direct transfers of material among themselves. Supply officers can use several databases to identify excess inventory and use the Other Supply Officer transfer procedure to fill deficiencies. However, this process relies on individual gumption rather than an enterprise-wide system.

G. SUMMARY

This chapter defined excess material and explained the current processes that relate to it. Excess inventory is any material held above the approved allowance level for that organization. There are five reasons why an item might become excess. Three of these involve enterprise-level processes, while the other two involve unit-level management. As of this writing (2012), there is no enterprise-wide process for redistributing excess material to units that need it. Current procedures delegate responsibility to individual units for redistributing or turning in excess material. Finally, the different accounts used to purchase material complicate efforts to create an enterprise-wide process.

We now build the foundation for the redistribution model by analyzing fleet inventory data to determine the total amount of excess and deficiencies by unit type and by region.

III. EXCESS MATERIAL DATA ANALYSIS

A. INTRODUCTION

This chapter describes how we calculated the current amount of excess material and deficient material among fleet units. It first provides a brief overview of the source database. It then describes the methodology used to analyze the data. Finally, it presents the current figures for excess and deficient inventory balances for the entire fleet, by type of unit, and by type of unit and region.

B. DATA SOURCE

The inventory data came from the Force Inventory Management Analysis Reporting System (FIMARS). FIMARS is a legacy database that stores inventory balances and other material characteristics for each unique stock item maintained by the reporting units. Ships and logistics squadrons submit inventory reports to the database twice a month, though type commanders have some flexibility to change the reporting frequency (Supply Procedures, 2005). Supply personnel can query the database through two different web interfaces, both of which are maintained by NAVSUP (Supply Procedures, 2005). The interfaces provide asset visibility that “is crucial to supply system responsiveness by ensuring that high priority requirements can be sourced under limited stockage conditions” (Afloat Supply, 2005, p. 6–25).

NAVSUP provided copies of the most recent 12 months of available FIMARS data, covering various periods from December 2010 to April 2012. Table 1 lists the data fields used by FIMARS.

Data field	Identifies
UIC	The reporting unit
Last report date	Date of the inventory information
Material Control Code	Item characteristics
Cognizance Symbol	The item manager (e.g., DLA or NAVSUP)
Allowance Type Code	Why the unit carries the item
CT code	Item characteristics
Federal Supply Class	Category of material (e.g., valve)
National Item Identification Number (NIIN)	Unique individual item
Nomenclature	Plain-language description
Unit of issue	How it is issued: Each, roll, package, kit, etc.
Average monthly demand	Average number ordered in a month
Frequency	How often the item is ordered
Reorder objective	High inventory limit
Reorder point	Low inventory limit
On hand	Amount of the item currently on hand
Stock due	Amount on order
Excess on hand	Amount above the allowance level
Excess due	Amount on order above allowance
Deficient	Difference between allowance and on hand
Unit price	Price of one unit

Table 1. Data fields used by FIMARS

C. METHODOLOGY

The FIMARS files were quite large, averaging about 6 million rows of data. We used Microsoft Access and Microsoft Excel to combine and analyze inventory, unit, and region information. We first eliminated those inventory records with no excess or no deficiencies. For the remaining records, we used pivot tables to determine the amount of material that could be redistributed globally, regionally, and within a given warfare enterprise. The following subsections describe this process in greater detail.

1. Incorporating Unit and Region Information into the Inventory Data

The FIMARS data sets provided by NAVSUP included all the inventory information needed to conduct the analysis. What the FIMARS data lacked, however, was detailed information on the units themselves, especially the type of unit (e.g., aircraft carrier, submarine) and its homeport.

We therefore created a separate data table to list these characteristics based on Unit Identification Code (UIC), an unique five-digit code that identifies each reporting unit. We gathered each unit's name and homeport information from the Standard Navy Distribution List (2012), the Navy comptroller's office, and the navy.mil website. Table 2 summarizes the data fields in this table.

Data field	Identifies
Activity title	Unit name in plain language
Unit category	Working capital fund ships or warfare enterprise
Decommissioned status	If ship is no longer on active service
Region	Geographic area of homeport
Subregion	Country of homeport (for Western Pacific activities only)

Table 2. Data fields in the UIC table

The UIC table has two data fields—Unit category and Region—that need additional explanation. We grouped the units into a material-type category based two factors: first, the "color of money" used to buy the inventory (NWCF or mission); and second, the warfare enterprise. Thus, all the ships using the Navy Working Capital Fund are together. For the remaining units, all the surface ships are together, all the aviation activities are together, and so on. In addition, we classified units by their geographical location. The size of these regions is based on a heuristic determination of "reasonable lateral supporting distance;" that is, we believed that the units within a given region were close enough that redistributing one additional item among them would incur a relatively small marginal transportation cost. Table 3 summarizes the criteria used to define each region.

Region	Geographic area included
East Coast	
Northeast	New Jersey to Maine
Virginia	Virginia
Southeast	North Carolina to Florida
West Coast	
Northwest	Washington state
Southwest	Nevada and California
Hawaii	Hawaii
Western Pacific	
Japan	Japan, including Okinawa
Guam	Guam
Diego Garcia	Diego Garcia

Table 3. Grouping the units by geographic region

2. Analyzing the data

After creating the UIC information table, we used Microsoft Access and Microsoft Excel to analyze the FIMARS data. We first used Access to link to each month's FIMARS data table with the UIC information table. We then created a query to eliminate records with no excess and/or no deficiencies and group the remaining data using Access's built-in SUM and AVERAGE aggregating functions. One important note: we took a conservative approach and eliminated the records from decommissioned units, though some (or possibly all) of these inventory items might still be available. Table 4 presents the data field settings used to compile the initial reports.

Unconstrained redistribution		
Data field	*Source*	*Aggregate function*
NIIN	FIMARS table	Group by
Excess On Hand	FIMARS table	Sum
Deficient	FIMARS table	Sum
Unit Price	FIMARS table	Average
Redistribution constrained by unit category		
Data field	*Source*	*Aggregate function*
Unit category	UIC table	Group by
NIIN	FIMARS table	Group by
Excess on hand	FIMARS table	Sum
Deficient	FIMARS table	Sum
Unit Price	FIMARS table	Average
Redistribution constrained by unit category and by region		
Data field	*Source*	*Aggregate function*
Region	UIC table	Group by
Unit category	UIC table	Group by
NIIN	FIMARS table	Group by
Excess On Hand	FIMARS table	Sum
Deficient	FIMARS table	Sum
Unit Price	FIMARS table	Average

Table 4. Query settings used to generate Microsoft Access inventory reports

Once we generated the inventory reports in Access, we quantified the amount of material to be redistributed by exporting the data to Excel and using the “IF” function. A simple if-then statement set the amount of each item to redistribute as the lesser of excess or deficiency (e.g., we cannot fill 15 widget deficiencies if we only have 10 widgets in excess). We then multiplied the amount of each item to be redistributed by the average unit price for that item from the original FIMARS data. (In some cases, different units reported different prices for the same item.) Finally, we used Excel’s SUM function to calculate the extended monetary value of all the items it is possible to redistribute. We call this value the “target of opportunity.”

D. THE UNCONSTRAINED TARGET OF OPPORTUNITY

In April 2012, the most recent month for which FIMARS data was available, we calculated a target of opportunity of roughly $171 million. That is, the Navy could have filled 1,097,859 reported inventory deficiencies across 47,797 items with excess material it already owned. This is not to say the Navy generates a target of opportunity totaling $171 million every month. The value we calculated for April 2012 represents years of slow inventory accumulation. Each month's total target of opportunity will vary slightly as different factors leading to its creation change. The total target of opportunity for each month of FIMARS data is listed in Appendix A. A sample of the April 2012 data is shown in Table 5.

Item (NIIN)	Excess on hand	Deficient	Average unit price	Amount to redistribute	Extended monetary value
000000058	40	48	$38.18	40	$1,527.20
000000060	35	35	$38.58	35	$1,350.42
000000172	37	36	$10.08	36	$362.88
000000182	10	10	$165.14	10	$1,651.43
000000189	4	9	$1,658.87	4	$6,635.48
			.		
			.		
			.		
SG0000816	1	2	$1.00	1	$1.00
SG0000868	1	1	$1.00	1	$1.00
SG0000910	1	2	$0.67	1	$0.67
XR0046649	3	4	$68.68	3	$206.05
XR0060010	12	3	$1.01	3	$3.03
TOTALS				1097859	$170,794,537.37

Table 5. Sample of April 2012 data with total redistribution values

E. CONSTRAINING THE TARGET OF OPPORTUNITY

The unconstrained target of opportunity makes two fundamental assumptions. First, it assumes that NAVSUP could work out the technical details of reimbursing each Type Commander (or the Navy Working Capital Fund) for redistributions that cross

funding accounts or cross warfare enterprises. Second, it assumes that it is always beneficial, in terms of cost, to redistribute the material (i.e., the transaction cost is small compared to the value of the item).

There are problems with both assumptions. Figuring out a reimbursement scheme is no easy task. In addition, it seems reasonable that the benefit-to-cost ratio decreases as the distance between units—and the corresponding shipping cost—increases. We therefore constrained the target of opportunity first by unit category, then by region.

1. Target of Opportunity Constrained by Unit Category

We used Excel's pivot table features to restrict the redistribution process to only those units within the same category. That is, excess material could only be redistributed from surface ships to surface ships, from aviation activities to aviation activities, and so on. By reducing redistribution opportunities, the potential benefit is much smaller: roughly $130 million, as compared to the unconstrained value of $171 million. Table 6 shows the breakdown between unit categories.

Row Labels	Sum of AmtToRedis	Sum of CostAvoid
AVN	20321	$5,645,838.44
CNIC	9080	$1,410,034.08
MARINES	6321	$2,725,439.46
MEDICAL	25338	$3,031,778.05
NWCF	630279	$59,760,795.40
SUB	29627	$10,517,677.24
SURF	128482	$28,934,066.69
Grand Total	**849448**	**$112,025,629.35**

Table 6. Redistribution opportunity constrained by unit category

The breakdown between categories is not unsurprising. The largest opportunity is within the Navy Working Capital Fund, which includes the aircraft carriers and other large ships. Table 6 depicts the breakdown graphically.

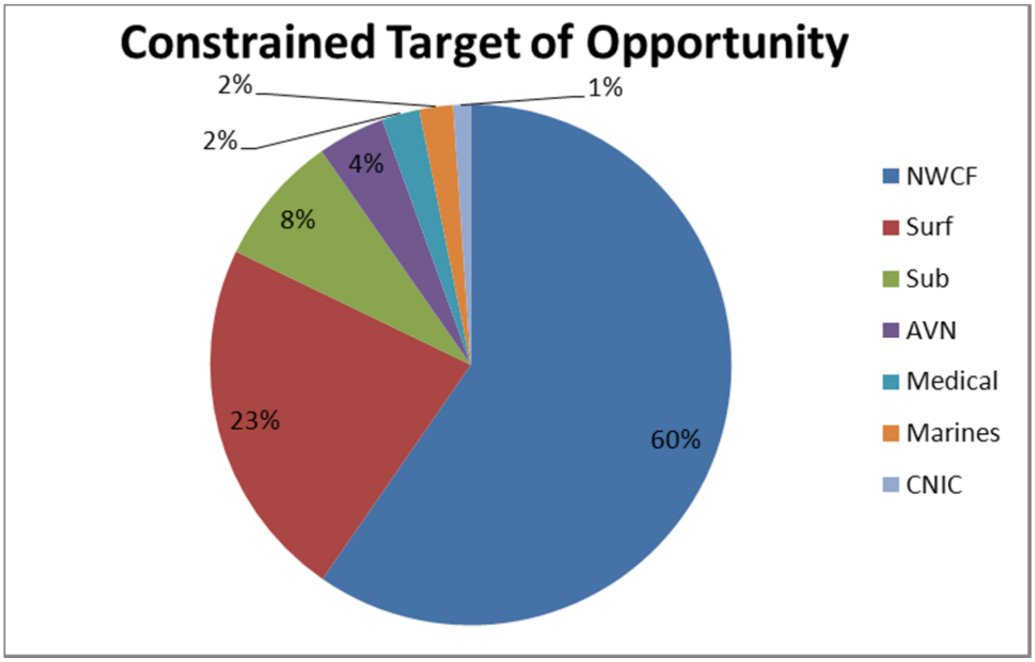

Figure 1. Redistribution opportunity constrained by unit category

2. Target of Opportunity Constrained by Unit Category and by Region

Finally, we constrain the target of opportunity by geographic distance. Consider the problem created if a redistribution model suggests transferring a $.50 O-ring from Yokosuka, Japan, to Norfolk, Virginia. The cost of shipping this item around the world may greatly exceed the benefit of redistribution. We therefore used Excel's pivot table function to constrain the target of opportunity by both unit category and region. That is, units could only redistribute excess material to other units within the same category (e.g., surface ship to surface ship) and within the same region (e.g., Virginia). The resulting target of opportunity is nearly $52 million, roughly a third or the original unconstrained opportunity of $171 million. Table 7 shows a detailed breakdown by unit category and by region.

Row Labels	Sum of AmtToRedistribute	Sum of CostAvoidance.
CENTCOM	**96**	**$25,884.81**
SURF	96	$25,884.81
GUAM	**588**	**$34,489.81**
NWCF	153	$3,645.77
SUB	435	$30,844.04
HAWAII	**12036**	**$2,707,889.32**
SUB	3372	$892,110.36
SURF	8664	$1,815,778.96
NORTHEAST	**4659**	**$824,124.17**
SUB	4659	$824,124.17
NORTHWEST	**113657**	**$4,535,555.94**
NWCF	110235	$3,351,051.17
SUB	3059	$916,711.73
SURF	363	$267,793.04
SOUTHEAST	**11936**	**$2,891,212.50**
MARINES	416	$431,980.18
SUB	3242	$501,561.69
SURF	8278	$1,957,670.63
SOUTHWEST	**159492**	**$7,278,768.39**
AVN	5195	$667,675.57
MARINES	450	$56,098.38
NWCF	134595	$3,062,434.40
SUB	1156	$200,508.04
SURF	18096	$3,292,052.01
VIRGINIA	**249954**	**$31,801,566.36**
NWCF	204416	$24,981,493.83
SUB	2363	$242,569.54
SURF	43175	$6,577,502.98
WESTPAC	**38725**	**$1,522,946.40**
AVN	143	$2,285.73
MARINES	109	$798.89
NWCF	32392	$522,086.45
SURF	6081	$997,775.33
(blank)	**0**	**$0.00**
(blank)	0	$0.00
Grand Total	**591143**	**$51,622,437.69**

Table 7. Redistribution opportunity by unit category and by region

F. LIMITATIONS OF THE ANALYSIS

This analysis is somewhat limited because it does not include information about each unit's *actual* location or its current position in the deployment cycle. This changes the target of opportunity numbers because deployed units might not have the ability to readily transfer their material. In addition, these units might be carrying excess inventory to support extended at-sea operations, in which case the material is not actually available for redistribution. It would also be advantageous for a redistribution model to prioritize those redistributions so that deficiencies among deployed or deploying units were filled first.

We also recognize that the FIMARS data may not be representative of historical inventory levels. Units are likely carrying greater quantities of excess material than they did in the past due to the recent Navy ERP implementation, which temporarily stopped excess material turn-ins and suspended allowance changes. Nevertheless, the data suggests there is a significant amount of excess material in the system, whether it is $171 million or $52 million. In addition, the processes described in Chapter II ensure that there will always be at least some excess material at the unit level.

G. SUMMARY

This chapter identified the source of our inventory data and described the methodology used to calculate the size of the redistribution opportunity. The analysis shows there could be significant benefits of redistributing material, even if those redistributions were constrained by both unit category and by region. The numbers are not written in stone; it is likely that not all of the excess material is available or that all of the deficiencies are required. Nevertheless, the data suggests that redistributing the excess material offers a significant opportunity. We next discuss the business rules and model required to achieve this significant one-time benefit.

IV. LATERAL TRANSSHIPMENT REDISTRIBUTION MODEL

A. INTRODUCTION

Based on our analysis of the provided FIMARS inventory data, the accumulation of excess on-hand inventory within the United States Navy provides for two areas of focus. In the short term, there exists a potential target of opportunity, or cost savings, through the one-time redistribution of excess material to fill existing fleet deficiencies. In this chapter, we discuss a model that yields a potential target of opportunity through redistribution of currently held fleet assets. In terms of future state planning, Chapter V focuses on the business rules needed to govern a steady-state, enterprise-wide system for redistributing excess material in a multi-echelon supply system using optional lateral transshipment to optimize inventory management.

This chapter provides an overview of our modeling methodology, describes a one-time NIIN redistribution problem, and analyzes the results. First, we define a problem setting in which a one-time lateral transshipment can be applied. Next, we explain the structure of the lateral transshipment model. We then apply this model to scenarios where positions of UICs are both static and dynamic. In closing, we provide analysis of the resultant target of opportunity and areas for further research.

B. METHODOLOGY

The overarching goal of this one-time redistribution model is to evaluate the potential target of opportunity derived from the treatment of individual fleet UICs as a single resupply point for peer UICs. We develop this redistribution model by adapting current corporate business models where a reactive transshipment model has been applied (Patterson et al., 2009).

The need for adaptation of those models stems primarily from their treatment of single-echelon transshipment resupply points as geographically fixed. Our team approached the model from both perspectives, intent on determining the potential target of opportunity if UICs were treated as both geographically static and dynamic entities. This is graphically represented by Figures 2 and 3.

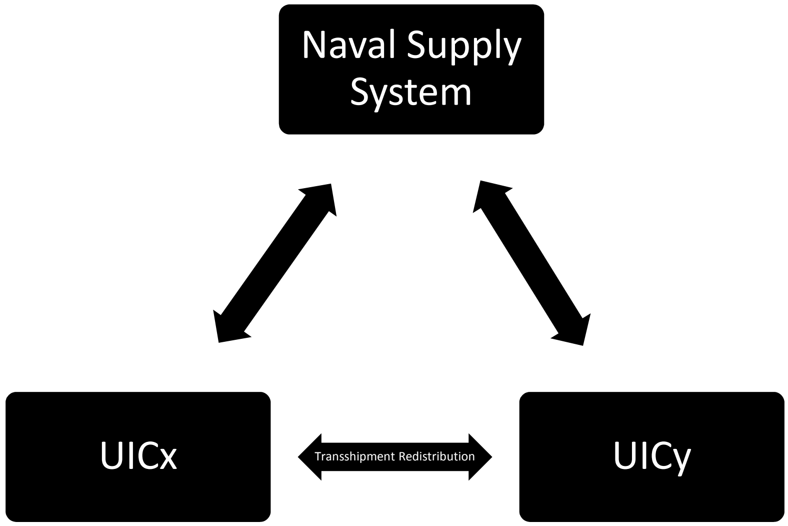

Figure 2. Proposed lateral transshipment redistribution: Stationary UICs

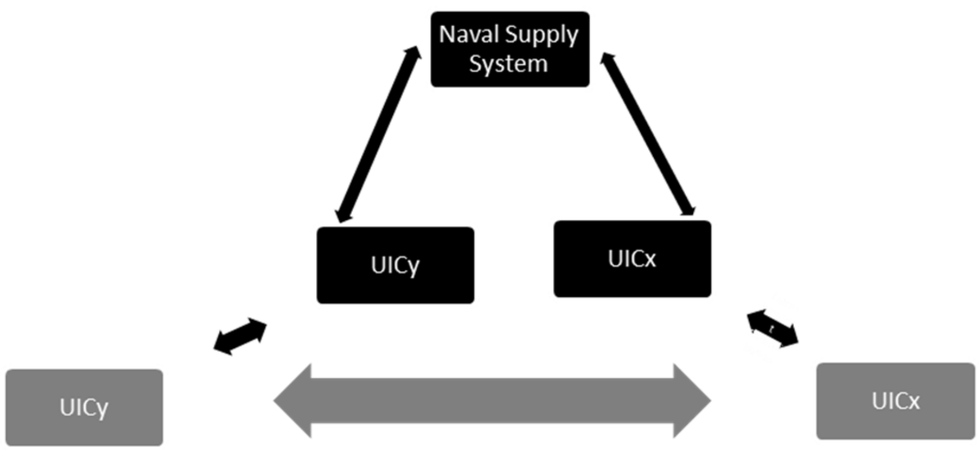

Figure 3. Proposed lateral transshipment redistribution for mobile UICs

Figure 2 represents the static position of UIC_x with respect to both the traditional Naval Supply System, the static multi-echelon component, and UIC_y, the static single-echelon peer. For real-world perspective, Figure 3 represents the dynamic position of sea going UICs with respect to the static Naval Supply System and dynamic UIC_y.

This is significant departure from the traditional single-echelon transshipment model on two levels (Axsäter, 2006). First, because the single echelon components have the potential to shift global position, their individual ability to act as a transfer supplier and/or transfer recipient can be impeded by their operational requirements. Second, the associated transfer transportation costs of dynamic UICs will fluctuate significantly with respect to the fixed cost structure expected of static UICs.

Our model is structured to determine the resultant target of opportunity through scenario generation where all UICs can be either static or dynamic. The actual transportation costs used to determine the target of opportunity were not available at the time we created this model. We used the commercial freight cost of a 10 lb. package listed in 2012 Federal Express Service Guide as a surrogate to establish baseline transportation expenses. The cost structure for shipment transfers is based on the distance travelled from supply point to demand point.

Subsequently, the cost structure was translated to the real-world positioning of UICs selected for the development of this model, as show in Table 8.

	FROM	Centcom		Hawaii		Northeast		Northwest		Southeast		Southwest		Virginia		WestPac	
TO		Zone	Price	Zone	Price	Zone	Price	Zone	Price	Zone	Price	Zone	Price	Zone	Price	Zone	Price
Centcom	Zone	2															
	Price		$5														
Hawaii	Zone	K		2													
	Price		$72		$5												
Northeast	Zone	K		9		2											
	Price		$72		$29		$5										
Northwest	Zone	K		9		8		2									
	Price		$72		$29		$7		$5								
Southeast	Zone	K		9		6		8		2							
	Price		$72		$29		$6		$7		$5						
Southwes	Zone	K		9		8		6		8		2					
	Price		$72		$29		$7		$6		$7		$5				
Virginia	Zone	K		9		4		8		5		8		2			
	Price		$72		$29		$6		$7		$6		$7		$5		
WestPac	Zone	K		G		G		G		G		G		G		2	
	Price		$72		$67		$67		$67		$67		$67		$67		$5

Table 8. Transportation cost structure matrix

where	
Class 2 =	0 to 150 miles between origin and destination
Class 4 =	301 to 600 miles between origin and destination
Class 5 =	601 to 1,000 miles between origin and destination
Class 6 =	1,001 to 1,400 miles between origin and destination
Class 8 =	More than 1,800 miles between origin and destination
Class 9 =	Shipments between the contiguous 48 states and metro Hawaii/metro Alaska
Class G =	Shipments from the United States to Japan (add $9 for Guam)
Class K =	Shipments from the United States to Bahrain
and	
(a) Price is based on distance, as determined by the Federal Express (FedEx) zone system	
(b) Price is for a 10-lb. shipment using the slowest available FedEx service	
(c) Prices are rounded to the nearest whole dollar	

Table 9. FEDEX shipping codes

The use of distance-based transportation shipping rates provides for a means to evaluate the cost effectiveness of laterally shipping a particular NIIN within the single-echelon structure. The method of lateral transshipment would rely on the existing availability of at sea UICs to absorb and/or disembark available inventory through vertical replenishment, carrier onboard delivery and or commercial delivery while in port.

C. PROBLEM SETTING

It is important to highlight that the excess on-hand inventory has already been purchased by a particular funding code. This means that a cost for purchasing excess inventory has already been incurred. Therefore, the potential target of opportunity is derived from the optimization of transferor (supply) to recipient (demand), where minimum lateral transshipment cost is endured. Additionally, in order to fill a deficiency outside of a lateral transshipment, funding would be required to purchase the item at the average unit price and then incur the costs to ship the item from vendor (or supply center) to UIC.

For this model, we consider a single-echelon lateral transshipment in which a single NIIN, with supply (excess on-hand) and demand (deficiencies) data provided through FIMARS. We constrained this particular problem to randomly generated supply and demand data for a fictitious NIIN, which would subsequently be laterally transshipped across all nuclear powered aircraft carriers (CVN). This ensured the commonality of the NIIN to all units, as well as blanketed the test group with a common

source of fund, in this case the Navy Working Capital Fund. This also allowed for the shipping of each item as an individual unit based on the 10-lb weight limit prescribed in the Federal Express shipping cost structure.

As opposed to the business rules that would govern steady state operations, we assume that since this is a one-time redistribution, the time to transport goods (lead time) between transferring UIC to receiving UIC is immaterial.

In this model, we selected all CVNs and determined their homeport location and current global position. This allowed for the evaluation of a scenario where lateral transshipment might be applied based on dynamic UIC location. The two scenarios used in the transshipment model would evaluate the transshipment costs between all UICs in the homeport status to serve as a baseline of potential target of opportunity assuming these units were geographically fixed. Under this scenario, the Class 9 transportation costs were assigned to all CVNs to show the maximum domestic costs when applied to CONUS only shipments. The second scenario utilized a mixture of Class-specific transportation costs based on the relative position of UIC_x to UIC_y for all possible UIC-UIC combinations. This is displayed in Figure 4 and in Tables 10 and 11.

Figure 4. Global CVN position in the scenario

This graphical representation implies that all CVNs are treated as dynamic UICs with respect to incurred transportation costs with respect to their homeports. This is based on the current global position of all CVNs as of the time of this model. This is further broken down by homeport and location status in Table 10.

CVN	Homeport	Location
ENTERPRISE	Norfolk, VA	Mid Atlantic Ocean
NIMITZ	Everett, WA	Central Pacific Ocean
DWIGHT D. EISENHOWER	Norfolk, VA	Persian Gulf
CARL VINSON	San Diego, CA	San Diego, CA
THEODORE ROOSEVELT	Norfolk, VA	Norfolk, VA
ABRAHAM LINCOLN	Norfolk, VA	Norfolk, VA
GEORGE WASHINGTON	Yokosuka, Japan	Philippines
JOHN C. STENNIS	Bremerton, WA	Persian Gulf
HARRY S. TRUMAN	Norfolk, VA	Mid Atlantic Ocean
RONALD REAGAN	San Diego, CA	Bremerton, WA
GEORGE H.W. BUSH	Norfolk, VA	Norfolk, VA

Table 10. CVN homeport and status

Table 11 provides for the actual allocation of shipping costs between peer UICs based on the point-to-point mileage provided by Federal Express.

	NIMITZ	**EISENHOWER**	**CARL VINSON**	**ROOSEVELT**	**LINCOLN**	**WASHINGTON**	**STENNIS**	**TRUMAN**	**RONALD REAGAN**	**GEORGE BUSH**
ENTERPRISE	9	K	8	4	4	G	K	2	8	4
Shipping Cost	***$29.00***	***$72.00***	***$7.00***	***$72.00***	***$72.00***	***$67.00***	***$72.00***	***$5.00***	***$7.00***	***$72.00***
	ENTERPRISE	**EISENHOWER**	**CARL VINSON**	**ROOSEVELT**	**LINCOLN**	**WASHINGTON**	**STENNIS**	**TRUMAN**	**RONALD REAGAN**	**GEORGE BUSH**
NIMITZ	9	K	8	9	9	8	K	9	8	9
Shipping Cost	***$29.00***	***$72.00***	***$7.00***	***$29.00***	***$29.00***	***$7.00***	***$72.00***	***$29.00***	***$7.00***	***$29.00***
	ENTERPRISE	**NIMITZ**	**CARL VINSON**	**ROOSEVELT**	**LINCOLN**	**WASHINGTON**	**STENNIS**	**TRUMAN**	**RONALD REAGAN**	**GEORGE BUSH**
EISENHOWER	K	K	K	K	K	K	4	K	K	K
Shipping Cost	***$72.00***	***$72.00***	***$72.00***	***$72.00***	***$72.00***	***$72.00***	***$72.00***	***$72.00***	***$72.00***	***$72.00***
	ENTERPRISE	**NIMITZ**	**EISENHOWER**	**ROOSEVELT**	**LINCOLN**	**WASHINGTON**	**STENNIS**	**TRUMAN**	**RONALD REAGAN**	**GEORGE BUSH**
CARL VINSON	8	8	K	8	8	G	K	8	6	8
Shipping Cost	***$7.00***	***$7.00***	***$72.00***	***$7.00***	***$7.00***	***$67.00***	***$72.00***	***$7.00***	***$6.00***	***$7.00***
	ENTERPRISE	**NIMITZ**	**EISENHOWER**	**VINSON**	**LINCOLN**	**WASHINGTON**	**STENNIS**	**TRUMAN**	**RONALD REAGAN**	**GEORGE BUSH**
ROOSEVELT	4	9	K	8	2	G	K	4	8	2
Shipping Cost	***$72.00***	***$29.00***	***$72.00***	***$7.00***	***$5.00***	***$67.00***	***$72.00***	***$72.00***	***$7.00***	***$5.00***
	ENTERPRISE	**NIMITZ**	**EISENHOWER**	**VINSON**	**ROOSEVELT**	**WASHINGTON**	**STENNIS**	**TRUMAN**	**RONALD REAGAN**	**GEORGE BUSH**
LINCOLN	4	9	K	8	2	G	K	4	7	2
Shipping Cost	***$72.00***	***$29.00***	***$72.00***	***$7.00***	***$5.00***	***$67.00***	***$72.00***	***$72.00***	***$6.00***	***$5.00***
	ENTERPRISE	**NIMITZ**	**EISENHOWER**	**VINSON**	**ROOSEVELT**	**LINCOLN**	**STENNIS**	**TRUMAN**	**RONALD REAGAN**	**GEORGE BUSH**
WASHINGTON	G	8	K	G	G	G	G	G	G	G
Shipping Cost	$67.00	$7.00	$72.00	$67.00	$67.00	$67.00	$67.00	$67.00	$67.00	$67.00
	ENTERPRISE	**NIMITZ**	**EISENHOWER**	**VINSON**	**ROOSEVELT**	**LINCOLN**	**WASHINGTON**	**TRUMAN**	**RONALD REAGAN**	**GEORGE BUSH**
STENNIS	K	K	4	K	K	K	G	K	K	K
Shipping Cost	$72.00	$72.00	$72.00	$72.00	$72.00	$72.00	$67.00	$72.00	$72.00	$72.00
	ENTERPRISE	**NIMITZ**	**EISENHOWER**	**VINSON**	**ROOSEVELT**	**LINCOLN**	**WASHINGTON**	**STENNIS**	**RONALD REAGAN**	**GEORGE BUSH**
TRUMAN	2	9	K	8	4	4	G	K	8	4
Shipping Cost	$5.00	$29.00	$72.00	$7.00	$72.00	$72.00	$67.00	$72.00	$7.00	$72.00
	ENTERPRISE	**NIMITZ**	**EISENHOWER**	**VINSON**	**ROOSEVELT**	**LINCOLN**	**WASHINGTON**	**STENNIS**	**TRUMAN**	**GEORGE BUSH**
REAGAN	8	8	K	6	8	7	G	K	K	8
Shipping Cost	$7.00	$7.00	$72.00	$6.00	$7.00	$6.00	$67.00	$72.00	$72.00	$7.00
	ENTERPRISE	**NIMITZ**	**EISENHOWER**	**VINSON**	**ROOSEVELT**	**LINCOLN**	**WASHINGTON**	**STENNIS**	**TRUMAN**	**RONALD REAGAN**
BUSH	4	9	K	8	2	2	G	K	4	8
Shipping Cost	$72.00	$29.00	$72.00	$7.00	$5.00	$5.00	$67.00	$72.00	$72.00	$7.00

Table 11. Dynamic UIC shipping matrix cost structure

The model utilizes a non-specific NIIN to meet the 10 lb. shipping weight that is the driver of these transportation values. This allows for cost consideration specifically when allowing for any form of underway replenishment.

For both the baseline and dynamic lateral transshipment evaluation, we utilized the following randomly selected supply and demand data. This was a FIMARs dataset extract which was selected solely on the basis that a greater excess on-hand inventory was provided. This was representative of the larger scale of excess on-hand inventory witnessed throughout our FIMARS dataset analysis (Table 12).

LABEL	UIC	COMMAND	IDENTIFIER	EXCESS OH	DEFICIENCY
A	03365	Enterprise	CVN65	5	0
B	03368	Nimitz	CVN68	1	0
C	03369	Dwight D. Eisenhower	CVN69	0	8
D	20993	Carl Vinson	CVN70	4	0
E	21247	Theodore Roosevelt	CVN71	0	3
F	21297	Abraham Lincoln	CVN72	4	0
G	21412	George Washington	CVN73	2	0
H	21847	John C. Stennis	CVN74	0	4
I	21853	Harry S. Truman	CVN75	3	0
J	22178	Ronald Reagan	CVN76	0	3
K	23170	George H.W. Bush	CVN77	3	0
			TOTAL	22	18

Table 12. CVN supply and demand

This data set was applied to the model to evaluate the potential target of opportunity for lateral transshipment with all CVNs located within the continental United States as well as their actual global position.

D. LATERAL TRANSSHIPMENT REDISTRIBUTION MODEL (ONE-TIME)

This model focuses on the one-time redistribution of excess on-hand material through lateral transshipment of fleet UICs to alleviate selected inventory deficiencies. The use of Risk Solver Platform ® was essential to handle a matrix that allowed for the 10 by 10 redistribution. A mixed-integer programming construct was used to allow for the decision to transfer (binary) and the decision of quantity of NIIN to be transferred being determined.

The objective function in this model is the maximization of the potential Target of Opportunity (TOO) that exists for shipping a specified NIIN quantity based on the average unit price less the shipping costs:

$$TOO = \sum_{i,j} \beta(-T_{ij} + C) \tag{0.1}$$

where β represents the quantity of a selected NIIN to transfer, T_{ij} is the cost of transferring a single unit of the selected NIIN, C is the average unit price of the NIIN, i is

the supplying UIC, and j is the receiving UIC. In this function, $i \neq j$ and both i and j $\in \{A,...,K\}$.

The constraints of this model deal with the total supply (excess on-hand) and the total demand (deficiency). Supply is represented by the following:

$$Supply = \sum_j \beta ij \leq \eta i \theta i \tag{0.2}$$

where ηi is the excess on-hand inventory for UIC i and θi is the binary decision variable (1 = yes, 0 = no) to transfer from i to j. Demand is represented by the following:

$$Demand = \sum_i \beta ij \leq \phi j \tag{0.3}$$

where ϕj is the deficient amount of a given NIIN for UIC j. For all transfers, $\beta ij \geq 0$ and $i \neq j$.

This model structure allows for the optimum amount of excess material to be transferred from one CVN to a peer CVN without providing for over shipment of demand. The results of this model are discussed in the following section.

E. LATERAL TRANSSHIPMENT RESULTS

Based on the demand and supply data previously generated (Table 12) the model provided results based on static and dynamic positioning of the CVNs. The average unit price of this particular NIIN was assumed to be $100.00. The theoretical cost avoidance, the cost savings absent of any incurred transportation costs, would be valued at $1,800.00. However, real-world transportation costs occur and were applied first to the baseline potential target of opportunity. This is the value derived from shipping 18 excess on-hand units to meet Fleet deficiencies in CONUS. In the second case, real-world transportation costs were also assumed based on CVN geographic position and applied to the model. The results of both scenarios are listed in Table 13.

NIIN Average Unit Price	$100.00
Total Excess	25
Total Deficiency	18
Theoretical Cost Avoidance	$1,800.00
Target of Opportunity (Ships Homeport)	$1,278.00
Target of Opportunity (Ships Deployed Per Config)	$913.00

Table 13. Lateral transshipment results (static and dynamic)

In the dynamic lateral transshipment scenario, the following ship-to-ship transfers were determined to alleviate prescribed fleet deficiencies (Table 14).

	USS Enterprise	USS Nimitz	USS Eisenhower	USS Vinson	USS Roosevelt	USS Lincoln	USS Washington	USS Stennis	USS Truman	USS Reagan	USS Bush
USS Enterprise		0	0	0	0	0	0	0	0	0	0
USS Nimitz	0		0	0	0	0	0	0	0	0	0
USS Eisenhower	1	0		4	0	0	0	0	3	0	0
USS Vinson	0	0	0		0	0	0	0	0	0	0
USS Roosevelt	0	0	0	0		1	0	0	0	0	2
USS Lincoln	0	0	0	0	0		0	0	0	0	0
USS Washington	0	0	0	0	0	0		0	0	0	0
USS Stennis	2	0	0	0	0	0	2		0	0	0
USS Truman	0	0	0	0	0	0	0	0		0	0
USS Reagan	0	0	0	0	0	3	0	0	0		0
USS Bush	0	0	0	0	0	0	0	0	0	0	
TOTAL XFERS FROM	3	0	0	4	0	4	2	0	3	0	2
	A	B	C	D	E	F	G	H	I	J	K
	USS Enterprise	USS Nimitz	USS Eisenhower	USS Vinson	USS Roosevelt	USS Lincoln	USS Washington	USS Stennis	USS Truman	USS Reagan	USS Bush

Table 14. Detailed transfer between ships

As expected, the model provided diminishing potential of target of opportunity returns as shipping costs were applied and CVNs become mobile. The potential target of opportunity was reduced by $522.00 for shipments within CONUS and by $887.00 for shipments to and from deployed CVNs.

F. SUMMARY

Our goal here was to demonstrate a possible modeling approach that could be applied to redistributing excess material throughout the fleet. The model uses current deployment status and commercial shipping costs. However, the need to determine actual shipping costs between all deployed units and their subsequent inventory status was beyond the scope of our analysis. The data set analysis focused on the potential Target of Opportunity for the fleet. The model intervenes to provide a possible pathway for correcting these deficiencies.

However, the analysis demonstrates that the model produces the optimal transfer combination matrix for a given NIIN and average unit price. This allows for the potential Target of Opportunity to be calculated and for the decision to actually transfer material.

The goal of this model was to demonstrate a process by which the current excess inventory could be redistributed. It is an opportunity to fill existing stock deficiencies within the United States Navy without incurring the additional cost of purchasing new inventory. The utility of this model is dependent on the actual unit price, the related supply and demand data at the time of decision, and the global position of single-echelon resupply points.

This model is scalable in terms of one NIIN extended over more UICs to realize the potential target of opportunity. As previously stated, the model here utilizes only CVNs to demonstrated the concept of single-echelon, lateral transshipment. This model is not structured in terms of scalability applied to more than one NIIN. In order to accommodate shipment of more than one NIIN, a certain degree of shipment consolidation would have to be applied. There exists a need to discuss the business rules for incorporation of lateral transshipments in naval inventory management practices. This will be addressed in the succeeding chapter.

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V. LATERAL TRANSSHIPMENT BUSINESS RULES

A. INTRODUCTION

We presented a very basic scenario and model which could perform a one-time reduction in accumulated fleet inventory excess through redistribution. However, the model does not address the long-term problem of how or why inventory excess is created and accumulated. Theoretically our model could successfully redistribute the entirety of the available target of opportunity around the fleet, only for the excess inventories to accumulate again over time. To prevent this from happening we have developed and analyzed several business rules in the form of logic trees that could be used to handle excess inventory. While the model in Chapter IV describes a reactive transshipment model, the business rules in this chapter try to move to a proactive model that could be incorporated into Navy ERP’s sourcing logic to systematically redistribute excess material enterprise-wide.

To help visualize how these business rules would function, we present the problem facing a long-term redistribution method in the fleet. We present three logic trees using elements of multi-echelon transshipment model theory to describe the business rules. Finally, we use a scenario similar to the one presented in Chapter IV to illustrate how the logic trees would function.

B. FORMULATING BUSINESS RULES

Much research has been completed concerning the usefulness of implementing lateral transshipment models in order to reduce stock-outs and increase service levels. Many of these research papers, however, are concerned with corporate inventory problems within single- or multi-echelon supply systems. While we seek to improve the manner in which the Navy distributes and maintains its inventory system, we must always remember that there are inherent differences between the Navy and corporate paradigms. One example that illustrates the problem is the fact that ships move around the globe. We have already partially addressed this problem in Chapter IV by demonstrating the difference between static UICs and mobile UICs. In particular, not

only will mobile UICs affect the transportation costs involved, but also affect whether a UIC is available to transfer parts at all. It may be unreasonable for a UIC on deployment to be expected to send a NIIN held in excess to a UIC that is currently in homeport or in dry dock.

We must also consider the possibility that implementing a redistribution model without business rules could create a situation of constant inventory turnover, or churn, in the system. Shifting NIIN allowances, deployment status, critical parts, upgrades and obsolescence of systems in the fleet can all contribute to a scenario where a supply department may be spending an inefficient amount of time shipping and receiving redistributed parts to the detriment of good inventory management. In order to prevent this, a basic set of business rules must be implemented before a proactive inventory redistribution policy is put into effect. It is important to further define the terms proactive and reactive transshipment model within the parameters of this paper. We used the definition provided by Paterson, Kiesmuller, Teunter, and Glazebrook (2009).

> In proactive transshipment models, lateral transshipments are used to redistribute stock amongst all stocking points in an echelon at predetermined moments in time. This can be arranged in advance and organized such that the handling costs are as low as possible. Since handling costs are often dominant in the retail sector, this type of lateral transshipment is most useful in that environment. Reactive transshipments respond to situations where one of the stocking points faces a stock out (or the risk of a stock out) while another has sufficient stock on hand. This kind of lateral transshipment is suitable in an environment where the transshipment costs are relatively low compared to the costs associated with holding large amounts of stock and with failing to meet demands immediately. (Paterson et al., 2009)

Translated into the naval environment we can relate the reactive transshipment to what happens currently in the fleet. If a UIC has a critical need for a NIIN to complete a mission, it can order it through the supply system and/or reach out to other nearby UICs that may have that NIIN to negotiate an Other Supply Officer transfer. In cases where the demand is urgent, the Type Commander or an expediting office might direct the transfer of material. The transshipment of the critical NIIN is accomplished by the fastest

available means and ignores transportation costs. This reactive system requires user intervention to initiate the transshipment and is often used to fill critical needs as fast as possible.

A proactive system, such as this project advocates, would instead use centralized data available through Navy ERP to identify situations where transshipments could be scheduled between UICs in order to reduce excess and fill allowance deficiencies. In other words, the proactive system would work in advance to reduce the probability that a shortage will happen. The proactive system would make use of regularly scheduled transportation such as underway replenishments in order to reduce the associated transportation costs. In addition, it could reduce instances of critical deficiencies which could affect mission readiness, or require a costly reactive transshipment.

C. THE LOGIC TREES

We present three separate logic trees that could help the Navy move from a reactive to proactive transshipment model. When designing the logic trees we included the purchase of a new part from wholesale inventory as a normal option, as it would be in the long term. Transshipment of excess material cannot fill the needs of the fleet, but in order to prevent accumulation any excess in the system must be available for transshipment. In this way transshipment is assumed to be a normal part of the supply chain instead of the current system which only considers it in emergency situations.

Three logic trees were considered for this project in order to best fill the needs of the fleet. Each logic tree focuses on one of three areas: minimizing lead time, minimizing cost, or maximizing readiness. Because units move around the world, and through a readiness cycle it is unrealistic to think that one logic tree could meet the needs of all units at all times. A unit just returned from deployment does not have the same material requirements as one currently deployed to a combat area. It follows that deployed units in combat areas should receive a higher priority to fill NIIN deficiencies and that (for example) increased costs associated with minimizing lead time should be more acceptable for those combat-deployed units for instance. It is also unreasonable to assume that a centrally managed supply system would prevent every shortage. The demands of

the combat zone insist that a system have multiple methods of sending parts to units in need. So in combat situations where a stock-out has occurred and a unit needs a replacement part we have designed logic trees to facilitate transshipments. In non-combat situations we will demonstrate how it may be more advantageous to use a cost minimization tree, readiness maximization tree, or a combination of trees.

1. Minimize Lead Time

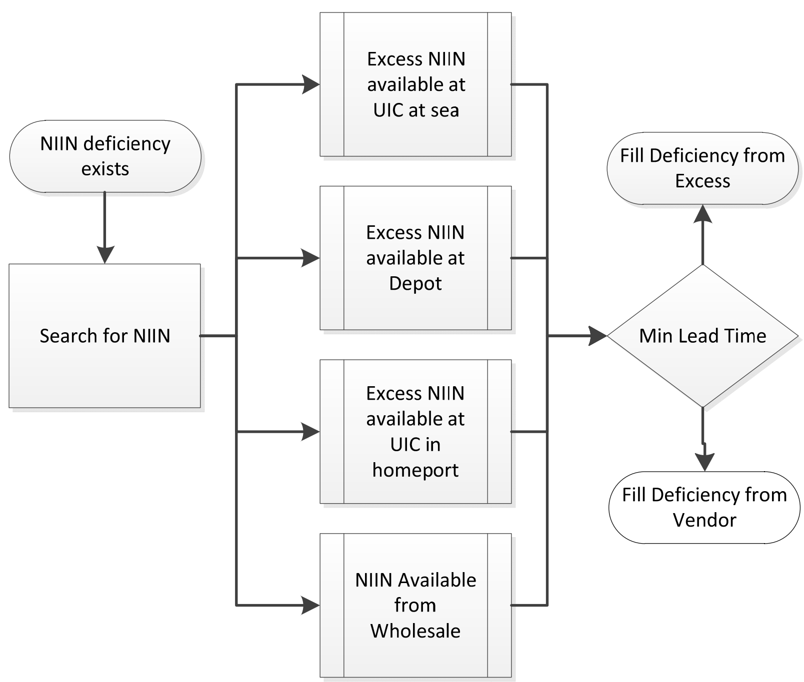

Figure 5. Lead time minimization logic tree

The logic tree in Figure 5 focuses on how to get a NIIN to a UIC as quickly possible while ignoring many associated costs. The system would search first for any available excess and second for any available wholesale supplies. Under this logic tree, the system chooses whichever option arrives soonest. For example, consider a CVN on deployment in the Persian Gulf that has a critical requirement. Assume that ERP found an

excess item on a ship in San Diego and a stock supply in Yokosuka, Japan. The system would compare the lead time of shipping the excess part from San Diego to the lead time of shipping a new part from Yokosuka, regardless of the shipment costs. However, the system would not recommend creating a deficiency on other operational units (e.g., a CVN on a training deployment off the coast of Japan). While that option is available in the reactive transshipment method, the intent here is to reduce such costly "double fills" by planning further in advance in a proactive way.

2. Minimize Total Cost

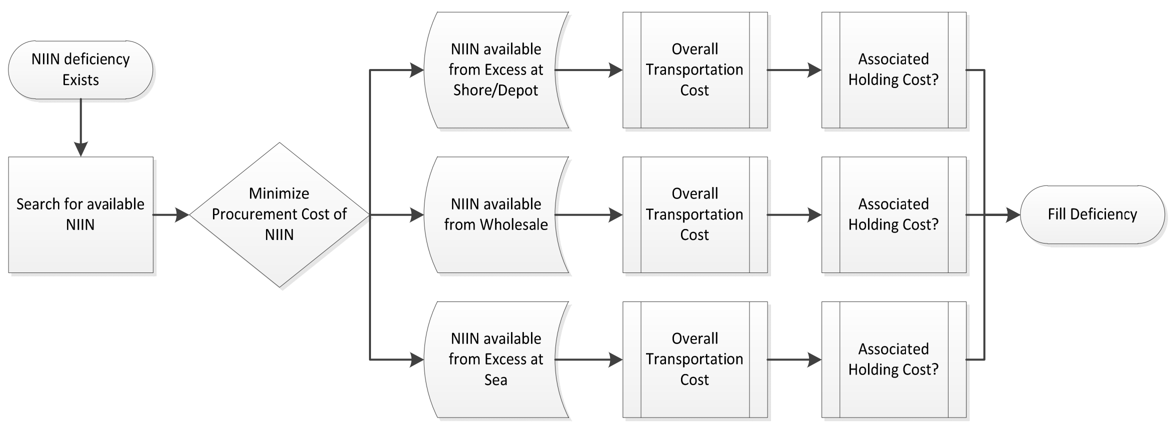

Figure 6. Minimize cost

Moving parts while ignoring shipment costs is unrealistic for the majority of redistribution cases and would negate much of the realized benefit. In order to prevent excess inventory from building up while still receiving the benefits from redistribution, a more cost conscious approach is required. The next logic tree was designed specifically to deal with this situation. This proactive approach would include transportation, holding cost, and excess inventory in the overall decision with a small concern with respect to lead time. This tree would represent how the majority of items could be redistributed because it would take advantage of the Navy's existing supply network. Instead of making special flights and deliveries to UIC's for emergency transshipments, this tree would attempt to schedule shipments during normal resupplies.

To understand how this would work, consider a UIC that has used a NIIN and is now deficient in that item. Under this logic tree, the system would search both excess material and wholesale supply inventory and compare the costs associated with each. If the cost of shipping an excess part from San Diego to a ship in the Persian Gulf is less than cost of shipping a part from wholesale stock in Yokosuka, then the system will choose to ship the excess part regardless of the lead time. The lead time for the part from San Diego may be much greater, but that is acceptable in this situation. The excess part can be moved with the rest of the supplies designated for the ship's next underway replenishment, which minimizes the overall transportation cost.

3. Maximize Operational Readiness

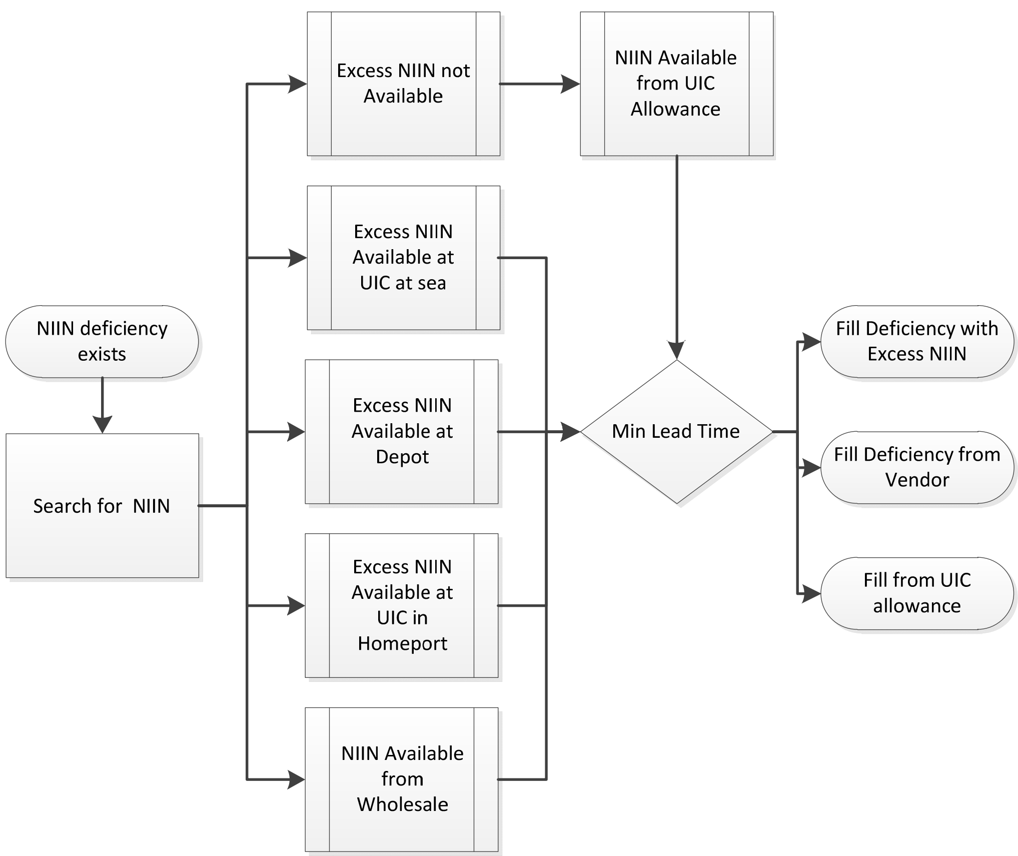

Figure 7. Maximizing readiness

The final logic tree was designed to cover those few situations where an emergency transshipment is still needed. This logic tree seeks to fill a NIIN deficiency as

fast as possible from any source available. The main difference between this tree and the Minimize Lead Time tree is that this tree attempts to maximize operational readiness by considering all allowance quantities, not just excess, as available for transfer.

To do so, the tree turns on a qualifier to look at other nearby UICs for an available NIIN in the unit's normal allowance. This process is similar to the emergency transshipment process that is already used by fleet expediting offices, but would be handled by a central system.

When a UIC reports it is has a critical requirement for a NIIN, the system would first search for excess NIINs, then search for wholesale inventory, and finally search all UIC allowances. Under this logic tree, the system chooses the option minimizes lead time regardless of cost and regardless of allowance position. If the part was sourced to another UIC's allowance, a replacement would then have to be ordered using the minimize cost logic tree. The lead time tree could also be used to send additional parts to our original UIC after it receives the NIIN required to complete its mission. This is important because although the UIC may have a working machine with the replacement NIIN, it is still deficient with respect to its allowance.

D. SUMMARY

In this chapter we discussed why the Navy needs a set of business rules to prevent the long term accumulation of excess inventory. By using a set of logic trees, it is possible to make use of excess fleet inventories to fill supply deficiencies and realize an overall benefit. ERP could be used as the driving force behind these redistributions instead of relying on a user-managed process.

The three logic trees we have developed are only a basis for further development and consideration. They are designed to broadly cover the general idea of how the Navy might use a redistribution system in the long term without incurring increased cost in transportation or manpower. They assume that the current method for dealing with excess material is inadequate, requiring revision and planning in order to realize a more efficient system.

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VI. RECOMMENDATIONS AND CONCLUSION

A. INTRODUCTION

This chapter provides the concluding remarks from our team in our effort to analyze and resolve the current state of excess on-hand inventory in the United States Navy. We provide a summation of our research, the problem solving approach to present and future state inventory management and conclude with areas of future research.

B. SUMMATION OF RESEARCH

The decision of the United States Navy to adopt and integrate Enterprise Resource Planning (ERP) as means for total financial, acquisition and inventory management is undoubtedly warranted. For decades, decision makers have largely been constrained to the information provided by a collection of legacy, stovepipe databases. The accuracy and accessibility of these systems to decision makers was limited at best.

ERP offers the Naval Enterprise the capability to streamline its business practices to provide for optimal decision making that directly affects the warfighter. Undeniably, the budget concerns of today will largely dictate how the Department of Defense elects to conduct business in the future. In turn, this translates to a need for all branches of service to operate in a leaner, more efficient manner. The real-time data management afforded by ERP implementation gives a platform by which decision makers are globally connected. This gives assurance that the most accurate fiscal position of the United States Navy drives each subsequent business decision. This provides not only strength to our customers, the warfighter, but allows decision makers to behave in a manner that produces fiscal stewardship to the U.S. taxpayer.

The overarching metrics for evaluating the efficiency of Navy Enterprise Resource Planning will be derived overtime from analysis of fleet operational availability balanced with meeting budgetary constraints. However, the mere application of ERP software will not alleviate all the problems that have amassed over time.

As evident through our research and data analysis of FIMARS, that has uncovered the existence of $171 million in fleet wide excess inventory. This is undoubtedly the product of suboptimal inventory decision making over time.

C. PROBLEM SOLVING: PRESENT

In our research, we sought to correct the $171 million in excess inventory through the use of mixed-integer programming. Our mixed-integer programming model, although limited to one NIIN across the entire fleet of CVNs, provided for an analysis of the cost efficiency of inventory redistribution. This covered the realm of the theoretical cost savings, baseline cost savings and deployment/real-world cost savings. Under the assumption that excess inventory is a sunk cost, the costs incurred through redistribution would largely stem from the transportation/shipping costs. The driving concept behind this redistribution, as well as our future state business rules, is largely derived on the concept of lateral transshipment.

Application of our redistribution concept across the entire fleet allows decision makers to determine when redistribution through lateral transshipment is cost efficient. The alternative would be to place further burden on the supply system, thus incurring unit cost and shipping costs. The scalability of our model was presumed to be either innate to ERP or easily implementable through software patching.

The data analysis provides for detailed categorization of the target of opportunity available to the Navy if utilization of excess inventory was emphasized. The lateral transshipment model provides for a means of correcting these deficiencies. However, this research does not suggest, nor recommend a mass push to redistribute inventory. The burden this would place on the supply system would significantly impede the operational readiness of steady-state operations and would test the limits of our supply system infrastructure.

Our team recommends an initial phased approach, where decision makers identify NIINs to be transferred based on mission criticality. This would allow for proper

evaluation of the redistribution under real world conditions. Subsequent redistributions could then be implemented to further drive down the overall excess inventory in the fleet.

D. PROBLEM SOLVING: FUTURE STATE

The intent of the redistribution model through lateral transshipment was to correct the accumulation of excess inventory. However, to whatever extent this model is applied by decision makers, it only corrects the current state of accumulation. There exists a need to apply business rules that govern how inventory management is governed in the future. In doing so, under the guidelines of the proposed business rules the buildup of excess inventory is not eliminated entirely but would be minimized. In order to completely eliminate the build-up of excess inventory decision makers would have to apply constraints on the ordering policies of individual UICs.

Instead, these business rules provide for a means of optimizing inventory through a combination of normal supply chain requisition and lateral transshipment. The hope is that all fleet deficiencies are met with application of the prescribed business rules in order to allow requisitions to be filled by the most cost efficient method. This constantly weighs the requisition of NIINs against all venues. Inherent to this design is the fact that the pool of excess inventory is constantly made available for redistribution. When cost effective, the pool is selected for redistribution and the quantity of excess inventory is driven down.

E. RECOMMENDATIONS FOR FUTURE RESEARCH

During the course of our research, we identified several areas that require additional investigation and could be useful in formulating future research projects. The most productive topics for future study include, but are not limited to the following: expanded NIIN data, real lateral transshipment costs, manpower costs and software costs.

FIMARS was the sole source for data extraction and analysis throughout our research project. Although, adequate in providing inventory levels, excess and deficiency, the data set failed to provide essential NIIN specifications. Our team found that dimensions and weight alone would have allowed us to tailor our model in a manner

consistent with the concepts of bundling. The model uses a fictitious NIIN of $100 average unit price and a weight of 10 lbs. This weight assumption allowed for the FedEx costs to be used without constraint. However, the need to ship smaller, less expensive units needs to be explored.

FIMARS also allowed for no reflection of operational status of the reporting UIC. This information could have allowed for prioritization of UIC deficiencies where the model does not specifically address operational commitments. Our model assumed real-time geographic positioning of CVNs based on research, but gave no weight to their status in the deployment training cycle, nor did it explicitly consider the fact that a deployed CVN may be moving targets for transshipment. This information would significantly drive redistribution constraints.

The last relevant NIIN specification to examine would be the applicability of NIIN with respect to component life cycle. If a NIIN could be identified as a component or part that is to be phased out over the near future, this would significantly slant the decision to utilize excess on-hand inventory rather than relying solely on wholesale inventory or vendor orders.

Transportation costs served as the driver for optimization of the potential target of opportunity produced through our redistribution model. The actual costs of transportation for lateral transshipments were not available. Our use of commercial (FedEx) shipping costs introduced a degree of uncertainty into the results. This was not necessarily a hindrance when shipping CONUS or OCONUS because commercial shipping is a viable method. However, the costs of ship to ship transfer through UNREP, VERTREP and COD replenishment methods were not specifically calculated. The actual costs of these lateral transshipments methods available to fleet UICs would give a more accurate picture of the savings available.

Assuming that redistribution of excess inventory is a path that decision makers want to pursue, the need to introduce labor costs becomes relevant. This decision would have a short term effect on the manpower supply of the Navy. The redistribution of such a large volume might require extended working hours or activation of reserve supply

units to facilitate total redistribution. This will be driven by the timeline and magnitude of NIINs to be redistributed. Supposing that current supply manpower levels are optimally used, there exists a need to factor in the opportunity costs of sailors working either solely or partially on redistribution and the degradation this could cause to operational readiness.

Implementation of the aforementioned redistribution model would require either adaptation of current ERP software or application of new coded software that would enable lateral transshipment as an option. This is also applicable to the implementation of the prescribed business rules. The complexity and costs associated with development, purchase, testing and upkeep provides for the largest area of concern by our team.

These recommendations provide not only room for explanation of our project deficiencies but also serve to highlight key areas of focus for further research. Costs, spread out over numerous areas will ultimately decide whether or not redistribution through lateral transshipment is fiscally sound for decision makers to pursue.

F. CONCLUSION

The overarching goal of this project has been to suggest that the Navy ERP can be used to not only shape the future of fleet business practices but can be used in a manner to address current problems and subsequently tailored to address business rules that optimize our inventory pool. Redistribution of current inventory through lateral transshipment solves the problem of excess inventory now but it also realigns our thinking for the future state. Single echelon transshipment in a multi echelon system gives decision makers more flexibility. The decision to treat our fleet UICs as warehouses requires total force compliance with ERP. This provides the visibility needed to make inventory management decisions that foster fiscal stewardship and promote the maximum availability of assets to the warfighter.

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APPENDIX

A. FIMARS DATA JAN-JUN 2011

	2011					
	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
BY NIIN	**$132,427,470.30**	**$137,100,003.22**		**$145,382,249.81**	**$145,382,249.81**	**$146,989,450.48**
BY CATEGORY	**$97,610,050.36**	**$103,485,014.31**		**$103,070,777.85**	**$103,070,777.85**	**$107,207,236.82**
BLANK	$2,047,184.25	$2,108,998.49		$2,328,683.08	$2,328,683.08	$2,811,032.68
AVN	$1,749,973.25	$1,875,310.61		$2,009,566.99	$2,009,566.99	$1,533,624.92
CNIC	$90,051.51	$105,244.73		$119,633.20	$119,633.20	$90,683.46
MARINES	$2,478,843.82	$2,303,830.45		$3,593,033.14	$3,593,033.14	$3,551,158.06
MEDICAL	$3,031,778.05	$3,031,778.05		$3,031,778.05	$3,031,778.05	$3,031,778.05
NWCF	$33,841,921.18	$39,442,353.89		$34,239,380.57	$34,239,380.57	$37,192,775.11
SUB	$12,169,654.41	$11,877,024.97		$11,340,562.02	$11,340,562.02	$10,096,865.84
SURF	$42,200,643.89	$42,740,473.12		$46,408,140.79	$46,408,140.79	$48,899,318.69
BY REG/CAT						
Blank	**$2,047,184.25**	**$2,108,998.49**		**$2,328,683.08**	**$2,328,683.08**	**$2,811,032.68**
CENTCOM	**$113,656.03**	**$90,746.81**		**$118,265.33**	**$118,265.33**	**$118,676.43**
SURF	$113,656.03	$90,746.81		$118,265.33	$118,265.33	$118,676.43
GUAM	**$21,048.26**	**$27,688.92**		**$32,032.58**	**$32,032.58**	**$39,644.17**
NWCF	$2,924.25	$2,792.73		$3,462.01	$3,462.01	$950.05
SUB	$18,124.01	$24,896.19		$28,570.57	$28,570.57	$38,694.12
HAWAII	**$3,276,617.77**	**$3,291,676.33**		**$3,693,317.14**	**$3,693,317.14**	**$4,677,839.36**
SUB	$1,241,189.51	$1,178,584.02		$852,798.14	$852,798.14	$871,361.73
SURF	$2,035,428.26	$2,113,092.31		$2,840,519.00	$2,840,519.00	$3,806,477.63
NORTHEAST	**$677,238.08**	**$674,244.83**		**$743,960.99**	**$743,960.99**	**$746,391.15**
SUB	$677,238.08	$674,244.83		$743,960.99	$743,960.99	$746,391.15
NORTHWEST	**$4,434,367.74**	**$4,449,495.58**		**$4,939,677.89**	**$4,939,677.89**	**$3,789,753.62**
NWCF	$1,099,094.23	$1,062,801.11		$1,746,379.26	$1,746,379.26	$1,081,552.56
SUB	$3,121,809.78	$3,173,259.05		$2,893,627.66	$2,893,627.66	$2,408,801.70
SURF	$213,463.74	$213,435.42		$299,670.97	$299,670.97	$299,399.37
SOUTHEAST	**$3,747,826.39**	**$3,704,108.47**		**$3,368,682.31**	**$3,368,682.31**	**$3,101,038.07**
MARINES	$50,903.39	$6,991.59		$10,519.91	$10,519.91	$25,181.61
SUB	$638,939.85	$654,681.85		$639,075.22	$639,075.22	$555,182.55
SURF	$3,057,983.16	$3,042,435.03		$2,719,087.18	$2,719,087.18	$2,520,673.91
SOUTHWEST	**$10,332,842.03**	**$8,142,023.44**		**$8,790,981.90**	**$8,790,981.90**	**$9,537,152.92**
AVN	$1,134,389.58	$1,036,453.46		$1,133,249.27	$1,133,249.27	$125,192.90
MARINES	$42,173.39	$17,023.56		$126,488.26	$126,488.26	$1,217,594.78
NWCF	$4,774,779.52	$2,992,794.32		$2,601,908.08	$2,601,908.08	$2,716,997.45
SUB	$151,239.00	$148,297.16		$175,435.58	$175,435.58	$218,614.59
SURF	$4,230,260.55	$3,947,454.94		$4,753,900.71	$4,753,900.71	$5,258,753.19
VIRGINIA	**$22,149,175.03**	**$22,065,128.05**		**$22,651,006.40**	**$22,651,006.40**	**$31,629,570.54**
NWCF	$9,367,478.45	$8,353,685.75		$7,089,122.93	$7,089,122.93	$16,012,453.92
SUB	$360,249.41	$369,289.94		$465,765.62	$465,765.62	$468,005.36
SURF	$12,421,447.17	$13,342,152.36		$15,096,117.84	$15,096,117.84	$15,149,111.26
WESTPAC	**$1,638,635.04**	**$1,722,803.38**		**$2,172,371.60**	**$2,172,371.60**	**$1,921,743.69**
AVN	$8,993.33	$6,622.32		$97,857.13	$97,857.13	$7,798.45
MARINES	$541.34	$5,597.11		$1,928.66	$1,928.66	$6,126.64
NWCF	$844,004.38	$878,218.03		$963,506.03	$963,506.03	$723,306.14
SURF	$785,096.00	$832,365.93		$1,109,079.78	$1,109,079.78	$1,184,512.45

B. FIMARS DATA JUL 2011–APR 2012

				2012			
	JULY	SEPTEMBER	OCTOBER	JANUARY	FEBRUARY	MARCH	APRIL
BY NIIN	**$225,323,480.96**	**$218,330,856.74**	**$245,558,389.23**	**$284,744,072.35**	**$267,773,772.49**	**$368,659,097.80**	**$170,794,537.40**
BY CATEGORY	**$142,051,208.38**	**$116,234,746.47**	**$135,692,888.66**	**$194,965,676.31**	**$173,017,248.57**	**$213,463,561.70**	**$112,025,629.30**
BLANK	$3,129,283.02	$3,577,422.72	$8,249,135.57	$3,849,940.60	$4,870,484.40	$14,193,113.89	
AVN	$1,052,061.39	$2,440,309.00	$7,360,206.06	$7,630,962.49	$3,522,365.40	$15,697,767.87	$5,645,838.44
CNIC	$157,746.92	$222,424.43	$147,947.86	$180,680.37	$676,059.46	$470,681.31	$1,410,034.08
MARINES	$28,331,023.24	$7,452,231.62	$4,163,578.13	$6,968,052.69	$24,936,203.16	$31,058,477.48	$2,725,439.46
MEDICAL	$3,031,778.05	$3,031,778.05	$3,031,778.05	$3,031,778.05	$3,031,778.05	$3,031,778.05	$3,031,778.05
NWCF	$43,666,601.22	$45,478,313.96	$53,759,064.04	$110,016,979.53	$91,524,397.28	$104,459,577.32	$59,760,795.40
SUB	$9,951,557.90	$8,362,172.05	$8,319,424.58	$19,603,871.42	$10,519,793.90	$9,652,798.41	$10,517,677.24
SURF	$52,731,156.64	$45,670,094.64	$50,661,754.37	$43,683,411.15	$33,936,166.91	$34,899,367.36	$28,934,066.69
BY REG/CAT							
Blank	**$3,129,283.02**		**$8,249,135.57**	**$3,849,940.60**	**$4,870,484.40**	**$14,193,113.89**	
CENTCOM	**$137,092.94**	**$135,038.97**	**$46,381.09**	**$39,273.88**	**$38,660.92**	**$41,281.33**	**$25,884.81**
SURF	$137,092.94	$135,038.97	$46,381.09	$39,273.88	$38,660.92	$41,281.33	$25,884.81
GUAM	**$39,220.79**	**$37,894.56**	**$37,652.32**	**$40,180.56**	**$37,441.52**	**$36,695.53**	**$34,489.81**
NWCF	$2,435.53	$1,117.53	$1,117.53	$3,645.77	$3,645.77	$3,645.77	$3,645.77
SUB	$36,785.26	$36,777.03	$36,534.79	$36,534.79	$33,795.75	$33,049.76	$30,844.04
HAWAII	**$4,000,895.45**	**$4,633,569.10**	**$3,711,709.48**	**$2,867,919.85**	**$3,112,544.45**	**$2,911,086.06**	**$2,707,889.32**
SUB	$887,042.83	$1,096,175.94	$1,009,897.32	$974,338.59	$1,070,813.49	$955,670.11	$892,110.36
SURF	$3,113,852.62	$3,537,393.17	$2,701,812.16	$1,893,581.26	$2,041,730.95	$1,955,415.95	$1,815,778.96
NORTHEAST	**$616,604.44**	**$739,795.21**	**$926,923.02**	**$557,236.68**	**$679,382.33**	**$793,503.34**	**$824,124.17**
SUB	$616,604.44	$739,795.21	$926,923.02	$557,236.68	$679,382.33	$793,503.34	$824,124.17
NORTHWEST	**$3,987,081.85**	**$2,193,405.56**	**$2,728,599.82**	**$9,890,692.57**	**$5,604,220.80**	**$6,073,704.15**	**$4,535,555.94**
NWCF	$1,090,274.08	$1,108,939.63	$900,295.94	$4,155,957.58	$3,921,968.61	$4,193,427.19	$3,351,051.17
SUB	$2,591,158.61	$785,464.67	$683,959.86	$4,602,317.76	$590,297.84	$665,318.29	$916,711.73
SURF	$305,649.17	$299,001.27	$1,144,344.02	$1,132,417.23	$1,091,954.36	$1,214,958.67	$267,793.04
SOUTHEAST	**$4,404,692.81**	**$3,797,565.82**	**$4,019,032.29**	**$2,269,639.67**	**$2,422,988.28**	**$2,999,048.13**	**$2,891,212.50**
MARINES	$1,844,185.08	$1,297,716.15	$93,039.07	$60,415.65	$60,648.94	$312,611.36	$431,980.18
SUB	$556,259.04	$522,418.05	$731,951.23	$481,482.40	$503,094.56	$512,541.90	$501,561.69
SURF	$2,004,248.70	$1,977,431.62	$3,194,041.99	$1,727,741.62	$1,859,244.77	$2,173,894.87	$1,957,670.63
SOUTHWEST	**$13,257,855.82**	**$7,857,092.35**	**$9,159,271.97**	**$18,547,378.37**	**$10,868,327.39**	**$10,643,285.19**	**$7,278,768.39**
AVN	$135,493.19	$224,133.80	$125,328.14	$130,166.81	$299,609.48	$268,449.04	$667,675.57
MARINES	$1,264,189.69	$87,991.19	$78,619.27	$159,327.47	$1,883,870.30	$263,763.00	$56,098.38
NWCF	$3,021,208.15	$2,419,877.34	$4,216,179.37	$7,321,369.33	$4,868,120.59	$6,754,843.09	$3,062,434.40
SUB	$202,422.85	$200,649.13	$108,442.24	$180,020.85	$153,983.73	$153,983.73	$200,508.04
SURF	$8,634,541.94	$4,924,440.88	$4,630,702.94	$10,756,493.91	$3,662,743.30	$3,202,246.33	$3,292,052.01
VIRGINIA	**$23,357,511.16**	**$24,623,205.76**	**$31,001,631.14**	**$31,037,418.32**	**$38,019,939.75**	**$39,849,355.42**	**$31,801,566.36**
NWCF	$8,747,222.83	$11,035,368.12	$17,230,833.04	$24,290,861.67	$30,907,037.83	$32,352,310.77	$24,981,493.83
SUB	$434,168.00	$636,401.38	$898,237.64	$762,453.63	$646,938.27	$237,196.54	$242,569.54
SURF	$14,176,120.34	$12,951,436.27	$12,872,560.46	$5,984,103.01	$6,465,963.64	$7,259,848.11	$6,577,502.98
WESTPAC	**$2,381,896.35**	**$2,371,801.50**	**$2,495,653.61**	**$5,547,379.66**	**$2,063,141.96**	**$1,984,946.25**	**$1,522,946.40**
AVN	$10,735.36	$28,168.35	$9,035.85	$16,257.82	$5,974.01	$6,518.45	$2,285.73
MARINES	$3,249.54	$2,614.19	$2,571.18	$78,573.30	$233,136.48	$212,155.04	$798.89
NWCF	$695,931.44	$639,604.03	$1,395,248.39	$4,434,104.10	$756,012.63	$787,017.88	$522,086.45
SURF	$1,671,980.02	$1,701,414.93	$1,088,798.19	$1,018,444.45	$1,068,018.84	$979,254.89	$997,775.33

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